United States
Environmental Protection
Agency

Research and Development

Air and Energy Engineering
Research Laboratory
Research Triangle Park, NC 27711

EPA/600/SR-92/053 April 1992

EPA

Project Summary

A Performance Evaluation of a Variable Speed, Mixed Refrigerant Heat Pump

P.I. Rothfleisch and D.A. Didion

The performance of an innovative heat pump, equipped with a distillation column to shift the composition of a zeotropic refrigerant mixture, was evaluated. The results of U.S. Department of Energy (DOE) rating tests and seasonal energy calcuations are reported with the main cycle refrigerant compostions. No composition shifting of the circulating refrigerant mixture was observed. To demonstrate the potential value of composition shifting, an ideal vapor compression cycle computer program was used to predict what the system performance would have been had the composition shifted. Seasonal energy usage calculations based on the computer predictions demonstrated that the effect of compostion shifting on the heating seasonal performance factor (HSPF) was very small, increasing slightly with climate zone. However, the savings in auxiliary heat were found to be substantial. In the cooling mode, computer predictions showed pure Refrigerant-22 (R-22) to have a seasonal energy efficiency ratio (SEER) approximately 2% higher than a mixture of 20% R-13B1 and 80% R-22 by weight.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Even though heat pumps are highly efficient, they find limited use in colder climates because of their reduced heating capacity at low outdoor temperatures. As the outdoor temperature falls, the suction pressure and the suction temperature also fall, causing both the suction vapor specific volume and the compression ratio to increase. The system heating capacity is thereby reduced, and the compressor work input is increased. The building heat load, on the other hand, increases as the outdoor temperature falls. These relationships are shown in Figure 1.

The outdoor temperature at which the building load equals the system capacity is called the balance point. If the outdoor temperature is below the balance point, the system capacity will be insufficient to satisfy the heating needs of the structure. In order to maintain the indoor temperature, the system capacity will have to be supplemented by an auxiliary energy source.

The auxiliary energy required for an entire heating season is the difference between the seasonal building load and the seasonal heat pump output below the balance point. The auxiliary energy is usually supplied by electric resistance heating, which has a coefficient of performance (COP) of 1. Since the COP of a heat pump is virtually always greater than 1, the HSPF can be increased by reducing the auxiliary heat required.

To reduce the amount of auxiliary heat required, the heat pump capacity must be

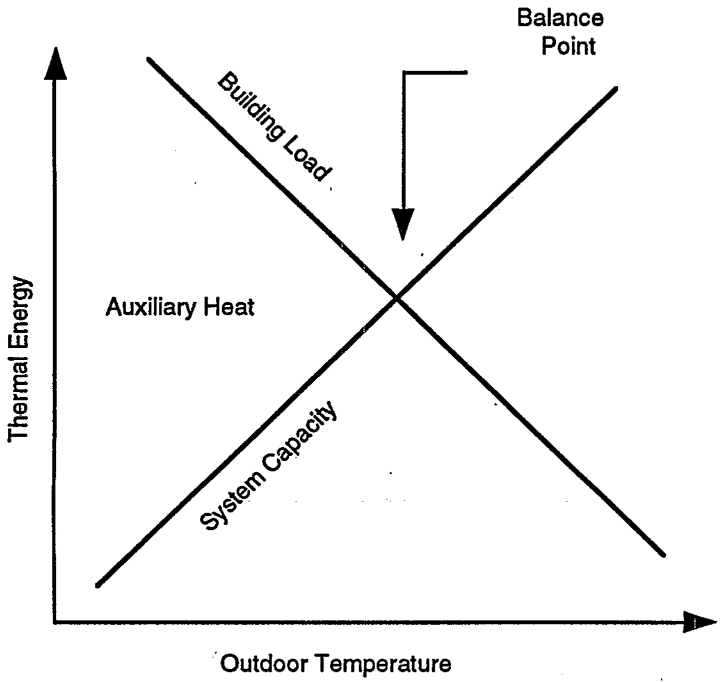

Figure 1. Building load and building system capacity versus outdoor temperature for a single speed heat pump operating with a pure refrigerant.

increased to match the building load as the outdoor temperature falls. The only commercially available heat pumps capable of matching system capacity to the building load have been those which vary the volumetric capacity of the compressor by using multi- or variable-speed motors. The system capacity can also be controlled by varying the composition of a zeotropic refrigerant mixture. The capacity increase that can be achieved by changing the composition of a refrigerant mixture has been demonstrated; however, the complexities involved with providing continuous composition control have limited its commercial applications.

In this project, the performance of an innovative new heat pump, equipped with a distillation column to shift the composition of a zeotropic refrigerant mixture, was evaluated. The unit is charged with a zeotropic refrigerant mixture of 80% R-22 and 20% R-13B1 by weight. The distillation column is intended to optimize the composition of the circulating refrigerant for different operating conditions. In the cooling mode, the column should separate and store the more volatile R-13 B1 component. In this way, the system takes advantage of the lower operating pressures and higher COP of pure R-22. In the heating mode, the capacity is increased to match the building load by shifting the refrigerant composition toward greater percentages of R-13B1. The properties of the resulting refrigerant mixture are much better suited to the low temperature heating application, than those of pure R-22. The unit is also equipped with a variable speed compressor which gives the system an additional method of capacity control.

There were two primary purposes for conducting this study: (1) to determine the extent to which the distillation column can control the composition of the zeotropic refrigerant mixture, and (2) to demonstrate that controlling the composition of a zeotropic refrigerant mixture can increase the HSPF and reduce the seasonal auxiliary energy requirement. This study was conducted utilizing a ductless split heat pump because its unique design incorporates both a variable speed compressor and a zeotropic refrigerant mixture to vary the capacity. While once commercially available, this design is no longer available because one of the refrigerants used (R-13B1) has a very high ozone depletion potential.

Results

The distillation column was expected to achieve the greatest degree of composition shifting that is practically possible in a residential heat pump. However, the unit did not demonstrate composition shifting in any of the tests.

The economy of instrumentation that was utilized to ensure a fair performance evaluation made it difficult to determine why no composition shifting occurred. However, one possible reason could be that excessive liquid refrigerant subcooling could have prevented the refrigerant from flashing in the capillary tubes leading to the distillation column and rendered it inactive. Another possibility which could prevent rectification is that the expansion valve was set with the resistance too low, causing most of the refrigerant to bypass the distillation unit. There was no way to determine this since the expansion valve was hermetically sealed and electronically driven.

Since the distillation column proved ineffective in controlling the refrigerant composition, the test shed little light on the value of composition control. Alternatively, a vapor compression cycle computer simulation program was used to simulate the system performance as if it would have shifted composition. Computer calculations were conducted for all the test heat source and sink temperatures with a refrigerant composition of 20% R-13B1 and another set of calculations were made with pure R-22 refrigerant as the cycle working fluid. Capacity, efficiency, and auxiliary heat requirement predictions were predicted using these data, assuming that ideal cycles can be used to predict relative changes in system performance. The calculations show that the increase in HSPF with composition shifting is negligible, but the resistance heat saved is significant, depending on the region for which the calculations were made.

Although this system failed to produce any composition shifting, the concept of rectification is still valid from the standpoint of auxiliary energy savings. If the test heat pump system is modified, additional experiments can be conducted, comparing variable speed operations and zeotropic mixture composition shifting as a means of capacity control.

☆U.S. GOVERNMENT PRINTING OFFICE: 1992 - 648-080/40233

P. Rothfleisch and D. Didion are with the U.S. Dept. of Commerce, National Institute of Standards and Technology, Gaithersburg, MD 20899.
Robert V. Hendriks is the EPA Project Officer (see below).
The complete report, entitled "A Performance Evaluation of a Variable Speed, Mixed Refrigerant Heat Pump," (Order No. PB92- 143 759/AS; Cost: $19.00; subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Air and Energy Engineering Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

United States
Environmental Protection
Agency

Center for Environmental
Research Information
Cincinnati, OH 45268

BULK RATE
POSTAGE & FEES PAID
EPA
PERMIT No. G-35

Official Business
Penalty for Private Use $300

EPA/600/SR-92/053